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Managing the Adoption of Geospatial Information and Technologies in Multiple Industries

Nor Liza Abdullah,[a*] Mohamad Rohieszan Ramdan,[b] Nurul Ashykin Abd Aziz,[c] Hazrul Izuan Shahiri[d] and Mohd Danial Afiq Khamar Tazilah[e]

Abstract: *In the era of the 4th industrial revolution, geospatial information has become essential for improving processes and enhancing task performance across the value chain, benefiting sectors such as agriculture, transportation, and logistics. Despite the widespread adoption of geospatial technology, understanding how to manage its adoption is crucial as technology continually evolves. This study aims to elucidate key aspects of managing the adoption of geospatial information and technology through a case study approach. The research involves interviews with Chief Executive Officers (CEOs) and directors from three different industries in Malaysia – agriculture, logistics, and transport – that utilise geospatial technologies. Thematic analysis of the interviews revealed four main themes: managing expectations of adoption, addressing factors of non-adoption, overseeing interactions in the adoption process, and ensuring the immersion of the technology. These findings provide valuable insights into the challenges and strategies for adopting new technologies, particularly those that transform traditional operations into technology-driven practices. The study's evidence underscores the importance of effective management in fostering the growth and economic expansion driven by geospatial technology.*

[a*] Faculty of Economics and Management, Universiti Kebangsaan Malaysia, Bangi 43600, Selangor, Malaysia; *Email: iza@ukm.edu.my*; ORCiD: https://orcid.org/0000-0003-2177-9570

[b] Faculty of Management and Economics, Universiti Pendidikan Sultan Idris, Tanjong Malim 35900, Perak, Malaysia; *Email: rohieszan@fpe.upsi.edu.my*; ORCiD: https://orcid.org/0000-0002-4899-7079

[c] Faculty of Industrial Management, Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuh Persiaran Tun Khalil Yaakob 26300 Kuantan, Pahang, Malaysia; *Email: ashykin@umpsa.edu.my*; ORCiD: https://orcid.org/0000-0001-9753-3257

[d] Faculty of Economics and Management, Universiti Kebangsaan Malaysia, Bangi 43600, Selangor, Malaysia; *Email: hizuan@ukm.edu.my*; ORCiD: https://orcid.org/0000-0002-1344-6074

[e] Faculty of Management and Economics, Universiti Pendidikan Sultan Idris, Tanjong Malim 35900, Perak, Malaysia; *Email: mohd.danial@fpe.upsi.edu.my*; ORCiD: https://orcid.org/0000-0003-2358-3168

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1. Introduction

Geospatial technology is making significant inroads into numerous industries, transforming traditional approaches into automated or digitally supported operations that enhance accuracy and optimise resources. Simple tasks become more effective with the advent of geospatial technology, while complex tasks become more accurate and economical to perform. Geospatial Information System (GIS) technology has revolutionised many industries, especially those related to infrastructure, environment, utilities, and healthcare (MGISS, 2023). In Malaysia, the extent of geospatial technology adoption varies depending on the industry type and the size of companies.

For example, the agriculture sector, which faces natural challenges such as the depletion of fertile land, air and water pollution, and climate changes, can benefit from precision agriculture or smart farming to optimise crop yields. The transportation sector is becoming more efficient with the use of the Global Positioning System (GPS), and the construction sector can reduce costs and increase accuracy using Building Information Modelling (BIM).

In addition, geospatial information and technology are becoming ubiquitous and increasingly important in our daily lives as the spacial element becomes integral to decision-making. The development of geospatial technology has fuelled economic growth by increasing accessibility to geospatial data and integrating GIS into everyday applications such as navigation apps and social media (Kumar, 2023). Furthermore, the emergence of web-based mapping platforms, the fusion of GIS with the Internet of Things (IoT), data analytics including big data and artificial intelligence (AI), and the rise of cloud-based GIS have increased the prominence of geospatial technology, demonstrating its pervasive role in multiple industries. Evidently, the growth and innovation in geospatial technology support the expansion of other industries, as all key economic segments leverage spatial information to improve efficiency and productivity.

The integration of geospatial technology is becoming increasingly widespread, despite the need for significant financial investment. However, the growth of the Internet of Things and the availability of free platforms like Google Earth and mobile applications are making geospatial data accessible at minimal cost, encouraging more players to exploit the technology. This paper aims to first describe the specific benefits of geospatial technology applications in three important industries: agriculture, logistics, and transport. Secondly, using a case study approach, the paper identifies and explains the different facets of adoption that companies need to manage to accelerate the adoption process while ensuring optimal benefits.

Finally, a model for managing the adoption of geospatial technology is developed and presented, encapsulating the findings to provide a meaningful understanding of technology adoption. Based on multiple lenses of geospatial adoption, this model can also be extended to the adoption of any new technology that will transform work systems and benefit the industry. This article presents a comprehensive model for managing the adoption of geospatial technology across agriculture, logistics, and transport industries, enhancing theoretical understanding of Technology Acceptance Model (TAM) and Technology Organization Environment (TOE) theory, providing practical strategies for companies, and contributing a robust methodological approach for studying technology adoption.

2. Literature Review

2.1 Adoption of Geospatial Technology

The extent of adoption of new technologies in business industries depends on the multitude returns that could be realised from the investments made involving the transformation of work processes (Preece, 1991). In the context of geospatial technologies, the ability of the technology to significantly enhance efficiency makes it more compelling to be applied in various sectors. Furthermore, as the technologies become more pervasive, it becomes more affordable and easier to be embedded in the work systems supported by strong leadership, robust IT infrastructure, and comprehensive training programmes (Kelly et al., 2023). The process of technology adoption typically begins with early adopters who recognise potential advantages and are willing to take initial risks, thereby demonstrating the technology's usefulness to others (Venkatesh et al., 2016). As benefits are realised, wider acceptance will support and accelerate applications, however barriers like reluctance to change, limited knowledge, and insufficient resources will impede progress (Pawar & Dhumal, 2024).

Geospatial technology encompasses a variety of tools and techniques used for collecting, managing, and analysing geographic and spatial data (Li et al., 2020). Technologies in this field such as GIS, GPS, and satellite-based remote sensing methods (Saran et al., 2020) provide real-time data that is essential in diverse areas such as emergency management, urban development, and environmental monitoring (Jiang, 2020). GIS technology especially becomes more compelling due to its extensive capabilities for data capture, input, update, manipulation, transformation, analysis, querying, modelling, and visualising various forms of geographic information through advanced software tools (Bonham-Carter, 2014). GIS functions as a comprehensive system designed for the systematic capture, storage, manipulation, analysis, management, and presentation of geospatial data (Chang, 2008; Lü et al., 2019).

With the advent of geospatial technologies, billions of gigabytes of geospatial data have been generated by governmental bodies and other stakeholders to enhance public convenience and accessibility (Dold & Groopman, 2017; Li et al., 2014). The surge in data production illustrates geospatial technology as a key instrument for addressing a broad spectrum of human and societal issues (Yusoff et al., 2021). GIS offers significant benefits by integrating multiple data sources into a unified system, which is essential for many industries especially those involve in spatial elements such as logistics, transportation and defence. Furthermore, advancements in GIS technology contribute to the development of more advanced models and simulations, enhancing predictive capabilities and real-time situational management (Murray, 2010). The fusion of GIS with emerging technologies like AI and machine learning further amplifies its effectiveness in handling complex spatial challenges (Himeur et. al., 2022). The growth of geospatial data and technologies underscore the transformative influence of information technology on decision making, thus making it critical to the delivery of quality services.

2.2 Benefits of Geospatial Applications

The implications of geospatial information and technology applications significantly impact economic events and influence multiple sectors, such as agriculture, urban planning, and disaster management. In agriculture, precision farming enabled by geospatial data can boost crop yields and resource efficiency, while in urban planning, geospatial technology supports the development of smart cities and improved land use planning. However as highlighted by Reynard (2018), these benefits come with budgetary challenges, particularly in gathering large quantities of geographical data. Data acquisition, technology, and software can be obstacles for businesses (Morgenroth & Visser, 2013; White et al., 2016) and public sector (Jozefowicz et al., 2020), but it gives benefits in terms of market analysis, logistics optimisation, and strategic planning. The costs may be prohibitive to smaller enterprises, however widespread application of IoT and availability of online platforms like Google Earth are making geospatial data more accessible at lower costs, thus reducing barriers for smaller companies and encouraging wider adoption. As embracing geospatial technologies improves operational efficiency, decision-making, and market competitiveness (Roe et.al., 2014), addressing these challenges to infuse geospatial technology becomes more critical to unlock significant economic growth and development across various sectors.

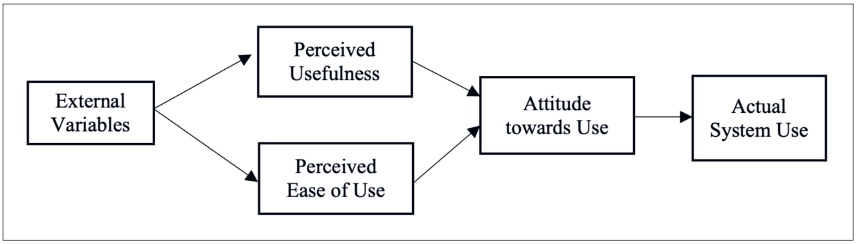
2.3 Technology Acceptance and Technology Organization Environment Model

The TAM is a key theoretical framework for understanding and predicting user acceptance of technology. It builds on Fishbein and Ajzen's Theory of Reasoned Action (TRA) by incorporating concepts such as perceived usefulness (PU) and perceived ease of use (PEOU), which are crucial for shaping users' attitudes toward technology and forecasting the likelihood of its acceptance (Davis, 1985, 1989). PU and PEOU determine how users perceive the benefits and usability of a technology, which directly influences their behavioural intentions. TAM's foundational insights is a valuable tool for understanding the factors that drive or hinder the adoption of new technologies, providing researchers and practitioners with a framework to design more effective user-oriented solutions.

Complementing TAM, the TOE framework offers a broader perspective on technology adoption by examining the interplay between technological, organisational, and environmental factors (Tornatzky & Fleischer, 1990). This model provides internal and external contexts of a firm's ability to adopt and implement new technologies. The emphasis on organisational readiness and external pressures makes TOE framework relevant for understanding the adoption of geospatial technologies across different industries. By combining

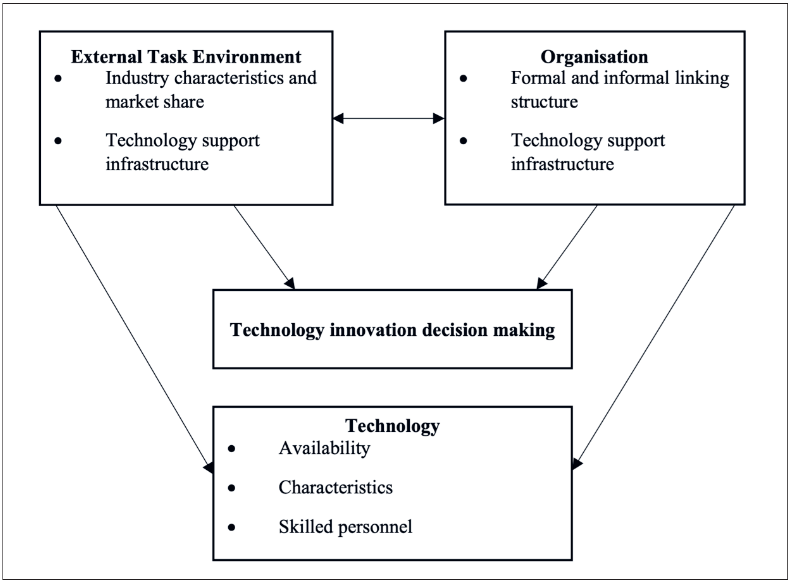
TAM model that focuses on user acceptance, with the TOE framework, a comprehensive understanding of the adoption process can be presented. The synergy addresses both individual and organisational factors, thus providing a comprehensive view for explicating how the adoption of geospatial information and technologies can be managed effectively in diverse industries. Figure 1 presents the TAM model, while Figure 2 illustrates the TOE framework.

Figure 1: Technology Acceptance Model



Source: Adapted from Davis (1989).

Figure 2: Technology-Organisation-Environment Framework



Source: Baker (2012).

3. Methodology

This study employed a qualitative research methodology using a case study approach to explore the related elements in the applications of geospatial technologies. Qualitative research methods, unlike statistical techniques, offer a deeper understanding of phenomena through direct engagement with data and participants (Corbin & Strauss, 2015; Denzin & Lincoln, 2018). According to Yin (2017), the case study method is particularly effective for examining complex issues. By focusing on detailed, real-world cases, this approach provided rich, contextual insights that are crucial for exploring the utilisation and impact of geospatial technologies in different settings.

The case study approach was selected due to its effectiveness in gathering detailed information on real-world events and challenges, which allowed for a nuanced understanding of the subject matter (Harrison et al., 2017). In this study, the case studies focused on organisations in Malaysia that employed geospatial technologies, revealing their practical experiences and highlighting the advantages and limitations of these technologies for operational tasks (Scârneci-Domnișoru, 2024; Younas & Durante, 2023). The research included three organisations from three sectors, i.e. agriculture, transport, and logistic. A structured interview protocol with high-level decision-makers was conducted to understand the applications and benefits, aspects of adoption, and impacts (Charmaz, 2014; Hoare & Francis, 2012).

The interviews were conducted at the premise of the company with a group of respondents selected by the company. As in any qualitative study, informed consent was obtained at the time of original data collection and the data collection for the purpose of presentation of the data, the respondents and organisations are properly anonymised. The background of the companies involved in the interviews is presented in Table 1.

Table 1: Description of Participants

Case study	Description	Position
Agriculture	Nature of business: Palm oil producer Size: 84,000 employees (globally) Revenue: RM18.43 billion	1 Research Director 1 Research Manager 3 Technology Officers
Transport	Nature of business: Highway operator Size: 3500 employees Revenue: RM4.27 billion (2019)	1 Operations Director 1 Geospatial Manager 2 Geospatial Officers 1 Data Officer
Logistics	Nature of business: Transporter for automotive parts Size: 250 employees	1 Operations Director 1 General Manager 1 Logistic officer

To analyse the data, thematic analysis was used to identify recurring patterns and themes related to technology adoption (Azad et al., 2021; Malterud et al., 2016). This approach involved a systematic process of coding, theme development, and interpretation, which allowed for a comprehensive examination of the interview data (Braun & Clarke, 2019; Fereday & Muir-Cochrane, 2006) aimed to uncover practical insights into aspects of managing geospatial technologies, offering a structured framework of adoption (Labra et al., 2019; Nowell et al., 2017). Thematic analysis offered flexibility while providing a rigorous approach to understanding subjective experiences, making it ideal for explorative research (Labra et al., 2019). Thematic analysis involves six stages; the first stage involves transcribing audio recordings of interviews, followed by reading the transcripts to identify the most relevant aspects of the participants' testimonies concerning the phenomena being studied.

Third is the initial coding phase where the researcher gathers data segments based on perceived patterns or themes (Braun & Clarke, 2012, 2019). From reading the transcription, themes or categories emerged from data elements or word sequences that provides concise and precise representation of the phenomena. In the fourth phase, a thorough evaluation of the themes identified in the third phase is conducted to provide a comprehensive description of the phenomena. The fifth phase involves two stages; the first stage is the detailed review of themes and subthemes, followed by the second stage where interpreting and defining ideas, concepts, and subthemes are performed. It is important for the thematic matrix to be re-analysed in this process to confirm the validity of hierarchical relationships and to ensure that the terms used at both levels aligned with the meanings suggested by the codes (Braun & Clarke, 2012). The final phase is presenting and discussing the findings (Labra et al., 2019).

4. Findings and Discussions

Based on the case studies, evidently all industries received benefits from the application of geospatial technologies. The application of geospatial technology in agriculture sector i.e palm oil concentrates on crop monitoring surveillance and past early detection. In the transport company, the focus of geospatial technology application is for the purposes of asset management and maintenance. Lastly, logistics achieves efficient operation that is translated into faster delivery and better cost management. The elaboration of the cases in the next section, gives an overview of the benefits received from the application of the technology.

4.1 Benefits of Geospatial Application

4.1.1 Geospatial Technology Application in Palm Oil Industry

In the agriculture sector, geospatial technology is an investment to boost production and quality of palm oil extraction. The use of geospatial technologies in agriculture is still at an infancy stage but increasing in Malaysia, and the extent of utilisation depends a lot on the type of technology. For example, GPS mapping has been used extensively with the introduction of GIS based supervision mechanism in farming system, and eventually has been upgraded to mobile app. The use of unmanned aerial vehicle (UAV) and geo tagging are still limited due to the restrictions in UAV handling and investment. Among big companies, the application of geospatial technologies is more pervasive with the in-house digital positioning supervision mechanism that allows structured and transparent field supervision of worker's performance via handheld GPS enabled devices. The advantage of using this system is that it allows immediate corrective actions to resolve operational issues, remotely manage harvesting operations in an efficient manner and provides real time data.

From the interview with the research and geospatial units, the company is aware of the positive impact, but also admits the need of huge investment to put the technology in place. Besides infrastructure, the level of knowledge and readiness at all levels in the organisation are needed to ensure a smooth transitioning of current work system to a technology laden work system. Resistance of application comes from various angles such as the learning requirements and the complacency of work routines. Among all, the most difficult to contain is the self-created resistance due to the ability of the system to evade malpractices among employees through geospatial tracking system. These possibilities pose a direct challenge to materialise the benefits, hence extra initial cost is incurred to train the personnel and changing the mind set to bring greater and sustainable return.

4.1.2 Geospatial Technology Application in Transportation Industry

Highway operators exploit emergent technologies in geospatial to monitor its asset management activities for optimum asset preservation. Geospatial technology plays a prominent role in preventive maintenance to identify defects for early intervention. Specifically, geospatial based maintenance management system was developed in-house to ensure that quality services can be delivered to highway users. According to the company, the expressway maintenance management and information system that is based on GIS and Relational Database Management System (RDBMS) contains all information related to inventory, asset condition and maintenance histories. The web-based software supported with up-to-date GIS application allows users to view GIS map harmoniously with a 360-degree panoramic view. The system also stores data related to slope management and flood prone zones and captures rainfall data to provide real time information for intervention in emergency. The system also constantly observes river water levels to inform possibility of traffic disruption due to flooding. In essence, the geospatial technology has made a significant contribution to the operation efficiency in highway services and the use of geospatial based maintenance system improves and facilitates the management of highway maintenances works and becomes substantive decision support tool.

4.1.3 Geospatial Technology Applications in Logistic Industry

Transport and logistics are both significant growth areas in Malaysia and provide customers with varied services ranging from individual transport and storage solutions to integrated supply chain management (SCM) services. The company involved in this study provides three major transport services: forwarding, warehousing and transportation services in Malaysia. Currently, the company benefits from the use of "milk run" technology to monitor delivery of merchandise in timely and efficient manner. The term "milk run" is defined as a set of delivery vehicles making multiple pickups and drop-offs at different locations on a regularly scheduled basis. GIS is used to schedule each delivery and drop-off and monitor the progress of the trips. The "milk run" using GIS has enabled the company to reduce its fleet of trucks by almost 50% and to handle more deliveries than previously. On top of mileage control, the employment of GIS system enables the company to ensure timely delivery as well as tracking hijacked goods. As a result, the operation costs have reduced significantly. This technology has also enabled a reduction in external costs such as pollution and road congestion by reducing the number of trucks in the fleet. GIS not only able to reduce operational costs, but it also provides additional values such as reduction of storage space at assembly plant; availability of extra space to make way for future project or expansion; decline in traffic volume; increase in truck operational efficiency; improvement in lead time; and returnable containers management. The benefits and economic impacts are summarised in Table 2.

Table 2: Summary of Benefits and Economic Impacts

Case Study	Geospatial technologies and tools	Nature of Benefits	Economic impacts
Agriculture	GIS GNSS GPS mapping Geotagging UAV Trimble receivers	• GPS mapping for legal and operational aspect • More efficient crop monitoring and inspection • Use for early past detection • GIS extensively use for workforce monitoring and operation management • Geo-tagging at trial stage – for identification of quality yield and detection of disease • Trimble receivers use for accurate mapping and drainage and pipe maintenance	• Higher yield • Reduction in cost due to timely pest control at precise location • Precise land data to avoid illegal encroachment • Timely preventive actions due to climatic challenges

Case Study	Geospatial technologies and tools	Nature of Benefits	Economic impacts
Transport	GIS GNSS GPS mapping UAV	• Use as decision support tool. • Preventive maintenance to identify defects for early intervention • Immediate solving of many problems through access to all the data. • Immediate accident management • Reduced asset management costs due to timely services.	• Stabilising cost management through preventive maintenance • Increase support and emergency services due to accidents and natural disasters • Efficient traffic management
Logistic	GIS GNSS GPS mapping	• GIS allows efficient management for delivery and warehousing • reduce truck fleet but more deliveries • mileage control • timely delivery and monitoring of crime/hijacked attempt • reduction in external costs such as pollution and road congestion by reducing the number of trucks in the fleet. • reduce operational costs • reduction of storage space at assembly plant • availability of extra space to make way for future project or expansion • improvement in lead time • improvement in returnable containers management.	• Reduce cost due to reduction in number of transports • Reduce maintenance costs • Efficient inventory and warehousing management • Reduce pollution due to efficient delivery system • Increase in safety practices

4.2 Managing Adoption of Geospatial Technology

The objective of the research is to understand the process of managing adoption of geospatial technology in company operations and accelerate the benefits from the application. Although geospatial technology is not new and has been used in many contexts, focused application to transform work system in a particular industry requires attention and understanding to spread the use to the entire industry for efficient operations. Based on the interviews, several aspects of managing the adoption of geospatial technology emerged as important elements in technology application as presented in Table 3.

Table 3: Distribution of Themes

Themes	Agriculture	Transport	Logistic
Managing expectations of adoption			
• Leadership	√		√
• Employees	√	√	√
• Stakeholders		√	√
Managing factors for non-adoption			
• Employee resistance	√	√	
• Taking advantage attitude	√		√
• The need to learn		√	√
• Stakeholders' readiness	√		√
• Cost of advanced geospatial technologies	√	√	
Managing interactions during adoption			
• Among employees/departments	√	√	√
• Among stakeholders	√	√	√
Managing the immersion of the technology			
• learning through training	√	√	√
• extending adoption of technologies	√	√	
• developing innovative and customised system	√	√	√

4.2.1 Managing expectations of adoption

People often get excited with the introduction of new technologies and innovations especially when the benefits were intensified in the long term. It is known that participants' acceptance and inclination to leverage technology will significantly influence the speed and intensity of adoption (Shang et al., 2021), but the data shows that there is always a gap between the benefits of technology and the expectations of participants. Managing leaders' expectation of adoption will be more challenging since they are responsible in making critical decision investing in the technology. As highlighted in the excerpt below:

> *"Plantation company is (also) like IT. When IT started 20 years ago people don't think much about IT; mainframe is so big, huge capital investment and then people started using emails, then the progression of technology itself are tremendous.* ***We are now as far***

> ***as the plantation in general, at a very expensive adoption phase****. Yes, the bosses got to see something because they heard it from overseas, (for example) farmer got GPS fixed to the tractor and it drives on its own. So, the bosses' concept of GPS and GIS would do miracle is there. It is over-expectation."*
>
> *Research manager (agriculture)*

> *"When the bosses see something like that (drone spraying pesticides), then they would say why don't* ***we substitute our workers*** *to do that."*
>
> *Geospatial manager (agriculture)*

> *"See* ***how the management sees the power of technology*** *and think about it in a different manner.* ***We think about enhancing efficiency****, their thinking – I can monitor where my guy is, and they are doing it."*
>
> *Research director (agriculture)*

The higher is the investment to embed the technology into the operations, the greater is the expectation on outcome, and the urgency to prove that the technology works becomes paramount. Managing expectations is not only limited to the leadership; it also involves all levels of employees in the organisation. The adoption of new technology will affect work directly or indirectly, and therefore managing expectations become more overwhelming to the department that championed the initiatives (Gupta, Yousaf & Mishra, 2020). As mentioned by a respondent:

> *"...****People get caught up in what the technology itself is all the about****; they don't understand what it can do…at the end of the day it is just a tool, it is just a mean to an end. And that is what people do not fully grasp the concept."*
>
> *Officer (agriculture)*

> *"****We can afford to invest in different types of geospatial technologies****, but what is most important is what we want to use it for, nice to have but can it actually do the work?"*
>
> *Research manager (agriculture)*

Therefore, managing expectations involves the ability to manage the technology to ensure that it works to establish its worth. An apparent assignment of new targets needs to be established and the results need to be communicated to get buy in from the employees. As mentioned below:

> *"The top management will assign new target, for example load efficiency,* ***fuel emission and consumption****. The load efficiency is achieved from the system and reported."*
>
> *General manager (logistic)*

> *"The GIS unit is established in 1998.* ***The intention of having the spatial data is to improve operation efficiency****. In this company, we use GIS to track and manage main fixed asset – our pavement, slopes, bridges, culverts, mechanical and electrical items, street lighting, signages, guard rails and fencings, these are our assets."*
>
> *Geospatial manager (transport)*

4.2.2 Managing factors for non-adoption

In many discussions on technology adoption, the focus is normally given to identify factors that drives adoption (Stornelli et. al., 2021). However, in ensuring a smooth transition of work system with the new technology, it is also important to manage factors that hinders adoption. Despite the general agreement on the advantage of geospatial technology, there will always be a group of late adopters who are sceptical, and this group need to be handled differently. As mentioned by one of the respondents:

> *"It is* ***not easy to convince people who are reluctant*** *to use technology despite the technology has advanced greatly."*
>
> *Research manager (agriculture)*

The factors of non-adoption can be also linked to the benefits of the technology. In the case of geospatial technology, its tracking ability using GIS and GPS will make work system more efficient, but to those who have been taking advantage of the traditional system will be impacted and therefore be reluctant to accept.

> *"There are cases of product theft, laziness, turning on the engine while sleeping;* ***all these can be avoided by technology****. In the case of petrol consumption, others reached 4 to 5 kilometres for 1 litre, why you can only achieve 1.7 kilometres – this is fishy, and something is wrong. Either you travel somewhere else or something wrong with the engine or you tapped the petrol somewhere. In terms of security, we can track the movement of the trucks."*
>
> *General manager (logistic)*

The exposure to new technology will encourage acceptance and stimulate absorption in the work process (Vecchio et. al., 2020). This is quite common because people normally will resist change and new technology need to be learnt and will affect complacency in work (Hertzum, 2021). Therefore, resistance is inevitable from different generation and levels of employees.

> *"The* ***new generation is more exposed to Waze, Google Maps and Street views****. Therefore, to the new staff from this generation, GIS is something that can be absorbed and easily appreciated.* ***The older generation is a bit slow and reluctant.****"*
>
> *GIS manager (transport)*

Since the adoption of new technology will also compels stakeholders to change (Li et. al, 2022), this becomes a challenge to the organisation to use new technology. As highlighted in the case of logistic industry, the need for vendors to join the bandwagon of new technology will determine the extent of the return from technology adoption.

> *"It is difficult to educate vendors – most of the vendors are reluctant because of costs."*
>
> *"Application of geospatial technology in the work processes is our marketing. However,* ***only few vendors are ready to use the system because they cannot understand the system and the work process****. It is quite challenging to get the stakeholders on board".*
>
> *Officer (logistic)*

From the data, it is obvious that managing non-adoption is often overlooked (Wolverton & Cenferelli, 2020) despite its importance to ensure smooth adoption and transition. The resistance can come from internal and external parties, and these need to be managed during technology adoption. As mentioned by the respondents, the stumbling block of adoption can be related to the institutional setting involving policies that regulate the technology. As evidenced by this excerpt:

> *"I would like to add on the data requirement. As I understand, G2G is always easier to get the data,* ***but G2GLC is actually not easy; it is a stumbling block to us****. If only we can get access the data. To access the data is not easy; there also some payments imposed."*
>
> *Officer (logistic)*

4.2.3 Managing interactions during adoption

The adoption of technology requires internal and external collaboration to ensure the adoption will bring greater benefits (Li et. al, 2022). Therefore, during the process of adoption, managing interactions between different groups are paramount to ensure adoption success. In the case of geospatial technology that deals with vast amount of data, the involvement of different entities in terms of data ownership, data collection and data management obligate all parties to play their role. Since the technology is just a tool, the process and the users will determine the effectiveness. As mentioned by a research manager:

> *"****Need to look at the technology and see can we use the technology to replace the workers*** *that you don't have, then maybe later you detect damage, you still need to get the workers on the ground and spray the crops. Your technology cannot do that. Just like Information Technology (IT) cannot do the work. It is just a tool."*
>
> *"When* ***we are already efficient using GPS, GIS, now we can make changes in terms of workforce and other resources.****"*
>
> *Research manager (agriculture)*

In other words, the interactions among the users of the technology need to be managed. From the data, the interactions involve internal parties at different levels and groups i.e. leaders and employees, different departments and external parties such as vendors, technology providers, government agencies and regulators. This is mentioned several times as reported below:

> *"The **stakeholders will be involved in monthly planning** of the delivery; manufacturer, transporter and vendor."*
>
> *Manager (logistic)*

> *"We even help our vendor, in terms of where is your delivery area, how is the packaging, we highlight security, **we teach them on safety aspects and we share and review with them the hazard map, and we benchmarked and ranked the vendor. More or less the vendors need to apply the system as well.**"*
>
> *General manager (logistic)*

> *"We also use geospatial in dealing with third party such as petrol station owner, especially on the mapping part. Thirdly, **we also provide data to other agencies for example about slope hazard adjacent to highway, although the data is not under our purview**. It is just on collaborative manner."*
>
> *GIS Manager (transport)*

> *"There are independent systems such as port inventory system, shipping line and custom system. So, **we need to collect the information to make it meaningful for decision-making**."*
>
> *General manager (logistic)*

Internally, important aspects of planning and execution need to be put in place to ensure that the immersion of technology is intense. This is evidenced when companies highlighted how inter and intra collaboration are needed to realise the benefits from the technology and encourage acceptance and appreciation. This is illustrated below:

> *"**Controller will use an interactive system to monitor collection and delivery**. Time management is very important, and daily planning is required."*
>
> *Officer (logistic)*

> *"**When we adopt this technology, we already have people with geospatial background**. However, the software is sophisticated. But still, we don't hire new people. **We send them for training, and internal training** for the company staff without geospatial background to **ensure acceptance**."*
>
> *Research officer (agriculture)*

The interaction during adoption may be related to different management functions. For example, the adoption of technology involves learning, retooling and reconfiguring of the existing resources (Cammarano, et. al., 2023). In the context of training and expansion of job scope, an example of managing interactions among different functions is given below:

> *"The drivers must be trained for example on the eco-driving skills. All information will be **recorded to identify efficiency per litre, one litre how many kilometres of travel**. And there is also speed monitoring. Drivers are also trained to load and unload goods. The drivers are fully utilized."*
>
> *Officer (logistic)*

Evidence of reconfiguration of resources is highlighted in the excerpt below:

> *"It has **significantly and will continue (reducing cost) because the way we are using it is to substitute what we can no longer sustain**. We cannot replace the man harvesting the fruit, but at some point of time, we are able to tell which field is due for harvesting earlier than another field. So that we can **divert our resources to those areas.**"*
>
> *Research director (agriculture)*

Basically, managing interactions is paramount because the applications require different parties to play its role to realise the benefits. The interplay of different sectors in different spectrum compels simultaneous adoption at different levels and entities. At some juncture, suggestions to have an independent body to drive the application at macro level is highlighted in the excerpt below:

> *"The investment is huge and even for a big company, asking for the budget is not easy. We **need collaboration and that is why we are working with other entities such as ATSB and universities**. In exploring a new technology, there is no way one organization can do it alone. There is a need for an independent steering committee that has no vested interest that allows liaison and collaboration."*
>
> *Research director (agriculture)*

4.2.4 Managing the immersion of the technology

Being a composite technology, the application of geospatial is incremental in line with the required investment. Spatial core technology is packaged in the form of GIS and GPS; without it the other technologies such as LIDAR, UAV and BIM cannot be fully leveraged. This is highlighted from the following excerpt:

> *"It has to be incremental steps, the first idea is to do the thing that you can no longer do, or no longer find people to do. That is logical approach. When you have reached that stage, then only you can go to **reduce the number of people that we have**. You don't jump from the first step and try to make changes abruptly. This is what the bosses expect. **Everybody is impressed by those kind of things.**"*
>
> *Research manager (agriculture)*

> *"....without being able to accurately determine where you are and at any time, whatever **information that you have after that is meaningless**. But knowing where you are anytime and anywhere, without GIS information behind it is also useless."*
>
> *Research director (agriculture)*

Therefore, managing the gradual process of technology immersion is expected to ensure that the technology is well received and embedded into current work system. There are three elements being highlighted from the thematic analysis: learning through training, extending adoption of technologies and developing innovative and customised system to maximise adoption. The elements can be seen as an incremental progression as the technology becomes immersed into the work processes. The adoption of new technology requires learning, unlearning and retooling to ensure the application of technology permeates in the organisation across functions and levels (Cammarano et. al., 2023). Majority agreed that geospatial technologies will increase process efficiency, however adopting this technology requires participants to learn and apply new techniques, change the work processes and develop skills to master the technology. This is highlighted in the following excerpt:

> *"When we adopt this technology, we already have people with geospatial background. However, the software is sophisticated. But still, we don't hire new people. We send them for training, and internal* ***training for the company staff without geospatial background to ensure acceptance.****"*
>
> *Research officer (agriculture)*

To a certain extent, some companies do not need new hiring, instead they just send their staff for training to equip personnel with the necessary knowledge.

> *"Despite increase in operations, there is no increase in terms of* ***personnel to monitor or control, and this constitute the benefits.****"*
>
> *General manager (logistic)*

To maximise the potential of the technology, learning must take place. Learning can happen through formal training organised by engaging external parties or in-house experts. In some cases, learning happened informally through multiple channels and best practices would emerge from the learning process. This is illustrated below:

> *"It has significantly and will continue (reducing cost) because the way we are using it is to substitute what we can no longer sustain.* ***We cannot replace the man harvesting the fruit, but at some point of time, we are able to tell which field is due for harvesting earlier than another field****. So that we can divert our resources to those areas."*
>
> *Research director (agriculture)*

> *"Recently we use the multi-spectre camera, and fitted in on the UAV and flew over and we try to look at Ganoderma. We want to pursue detection;* ***we don't want to wait until the oil palm is severely affected, we want to see early symptoms (so that) we can treat the palm and we want to identify the location****. When we flew the multi-spectre, we managed to detect. But when we go to the ground, same symptoms that were displayed by Ganoderma palm also displayed by water-logged palm."*
>
> *Research officer (agriculture)*

When the core technology is established, extension of technology adoption becomes easier as the benefits are materialised to the stakeholders. The leadership is also convinced to increase investment based on achievements and technology evidence. As mentioned by a research director:

> *"****The leaders are very generous in terms of expenditure on technology****, and we have the financial capacity."*
>
> *Research director (agriculture)*

If the technology being regarded as essential, extension to other related technologies becomes incumbent as more benefits can be leveraged from the investment in the core technology. Starting from GIS, extending data collection using LIDAR, UAV and BIM becomes necessary because the quality of data in terms of accuracy captured by these technologies gives greater impact on decision-making.

> *"From my point of view on remote sensing, the advancement of technology is quite fast. When you look at UAV within 5 years,* ***the technology is progressing rapidly and has promising potential moving forward****. But we have to explore the adoption in our*

context; we have to look at different aspects – implementation part, commercialisation part and what is the scale of data requirement to next stage. Geospatial will be the main player in the future of agriculture."

Geospatial officer (agriculture)

"Mapping is done for legal reasons according to company requirement – ***boundary, overplanted. Helps to settle dispute. Trimble receivers are used to increase the quality of the data****."*

Research manager (agriculture)

"Moving forward from BIM, we are ***going to digital engineering, it is still at a preliminary stage.****"*

Geospatial technology officer (transport)

"As the technology advances, we also ***extend the extensiveness of the technology we applied****. In our case is collecting data using LIDAR."*

GIS manager (transport)

Developing and innovating customised system to maximise adoption of technology is apparent in most industries. In other words, the adoption leads to internal innovation (Liu et. al, 2017) as companies sees the requirement of the company is unique and need adaptation. As mentioned in several cases:

*"****The new system that we are currently enhancing can track the actual time of arrival****, and use of colour coding to indicate the status of delivery whether it is on time or delayed."*

Officer (logistic)

*"****The system was initially bought from Japan, but then we developed locally because there were a lot of restrictions****. However, with the new plant, our main vendor requests us to use their system, but the existing system can be used for cross-checking."*

General manager (logistic)

In some cases, the use of technology needs to be supported by traditional work processes because some important data could not be captured by technology alone. Despite geospatial technologies enhances the breath of data collection and expediting processes and increasing efficiency, important data may not be captured due to the inherent nature of the technology. As illustrated in the case of agriculture, the data collected may be misconstrued and lead to wrong decisions. This is highlighted in the following excerpt:

> *"Recently we use the multi-spectre camera, and fitted in on the UAV and flew over and we try to look at Ganoderma.* ***We want to pursue detection; we don't want to wait until the oil palm is severely affected, we want to see early symptoms (so that) we can treat the palm and we want to identify the location****. When we flew the multi-spectre, we managed to detect. But when we go to the ground,* ***same symptoms that were displayed by Ganoderma palm also displayed by water-logged palm.****"*
>
> *Research officer (agriculture)*

> *"We have spent a lot to have this 360 panoramic view data.* ***We also need to spend to develop application****. On top of that, we are also doing manual data collection because when we use LIDAR, the detail attributes are not there."*
>
> *GIS Manager (transport)*

Based on the evidence, it is interesting to note that adoption of geospatial technologies needs to be viewed as incumbent, yet not all-inclusive. Therefore, the management needs to understand the work requirements and understand the limitations of the technologies. As mentioned earlier, the expectations may fall short and need to be managed to maximise the benefits.

> *"In the context of milk-run, of course we need the system, we need GPS and we need* ***the technology to support calculation of replenishment. In terms of transportation****, we monitor three aspects; delay or advance or non-delivery, speeding and geo-fencing, meaning to track compliance to the route."*
>
> *General manager (logistic)*

The development of customised GIS is done to meet the requirement of the company. Based on the experience of using the technology, the company would advise the development of supporting system to ensure effective application.

> *"**The tools made available to us by the technology facilitates the study of all those things (environmental related issues)**. That is why we have made high conservation liberia; every time we want to expand, we are facing pressures from NGOs. You cannot do this type on ground survey; you had to use remote sensing because of the cost involved and we are covering a large area. This is only made possible with geospatial information."*
>
> *Research manager (agriculture)*

The exposure and experience using the technology will ignite internal initiatives to extend the use of the technology by exploring related tools. Taking the scenario of highway operator, LIDAR technology is eventually used as the company sees the advantage of having extensive 3D elevation data generated by the technology. Interestingly, the data collected was shared to related agencies and therefore the benefits were extended, and the return of investment is amplified.

> *"We also use geospatial in dealing with third party such as petrol station owner, especially on the mapping part. Thirdly, we also provide data to other agencies for example about slope hazard adjacent to highway, **although the data is not under our purview**. It is just on collaborative manner."*
>
> *GIS Manager (transport)*

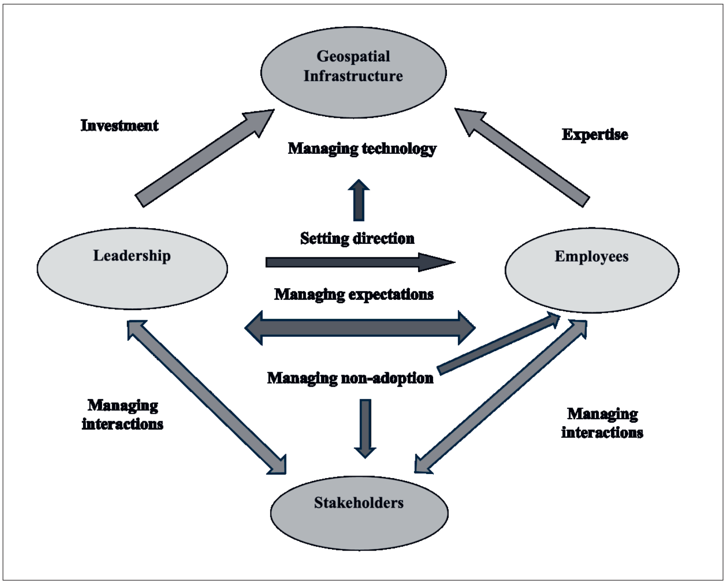
4.3 Discussion

The findings reveal that both internal adoption and external advocacy are key drivers compelling companies to embrace new technologies. Internally, factors such as financial capacity, leadership, and existing work systems and cultures significantly influence the pace of adoption. Externally, government policies, agency support, competitive pressure, and the availability and cost of technology play crucial roles in accelerating this process. Interviews indicated that as awareness of geospatial technology grows, companies become more receptive to related technologies, thereby speeding up the integration of comprehensive systems into their work processes.

From these insights, a model for managing the adoption of geospatial technology in various Malaysian industries has been proposed. This model outlines four critical aspects: (1) managing the expectations of leadership and employees as the technology is introduced to enhance work processes; (2) addressing non-adoption issues among employees and stakeholders such as vendors, suppliers, and agencies, as synchronised adoption is crucial for maximising the technology's benefits; (3) facilitating technology immersion, recognising that geospatial technology can be enhanced through the integration of other related technologies; and (4) coordinating interactions among various stakeholders to ensure the full utilisation of the technology. The model emphasises the central role of organisational leadership in accelerating the adoption timeline and ensuring broad and effective implementation. This is consistent with Kelly et al. (2023), who note that technologies that are simple to implement and significantly boost productivity are more likely to be adopted quickly, particularly when supported by robust IT infrastructure, capable leadership, and comprehensive training programs. Additionally, Shen and Zhang (2023) highlight the necessity of developing thorough strategies that account for external factors to ensure effective technology implementation.

In the context of geospatial infrastructure, leadership decisions to invest in and promote the use of technology are the starting point for adoption. Employees also play a crucial role by contributing their expertise to fully leverage the technology. This aligns with Jiang (2020), who notes that technologies are essential in fields such as environmental monitoring, urban development, and emergency management, providing a strong foundation for integrating near-field or real-time data. Furthermore, Yusoff et al. (2021) support this by noting that advancements in information technology have made geospatial technology an invaluable tool for addressing various social and human challenges. Employees' involvement is essential, as they must learn, adapt, and shift their mindsets and cultures during the adoption process. In the case of geospatial technology, simultaneous adoption among all stakeholders ensures maximum benefits, as the technology's value must be recognised by everyone in the value chain. This is corroborated by Roe et al. (2014), who state that adopting geospatial technology can improve decision-making, operational efficiency, and market competitiveness, leading to innovative solutions and cost reductions through economies of scale. As Pawar and Dhumal (2024) suggest, increased acceptability of geospatial technology will accelerate its applications, while obstacles such as resistance to change, lack of awareness, and insufficient funding can hinder progress. Figure 3 presents a model for managing geospatial technology adoption developed in this study.

Figure 3: A Model of Managing Geospatial Technology Adoption



Source: Authors.

4.4 Implications

This study has several significant implications. Theoretically, the study advances our understanding of technology adoption, especially within the domain of geospatial technology. By constructing a comprehensive model that addresses various aspects of adoption, the research provides a versatile theoretical framework applicable to other emerging technologies. This model illuminates the dynamic interplay between technological, organisational, and environmental factors, enriching the existing literature on technology adoption theories such as the TAM and TOE framework.

Practically, the findings provide actionable insights for companies in agriculture, logistics, and transport on how to effectively manage the adoption of geospatial technology. By identifying specific benefits and critical adoption facets, companies can craft targeted strategies to streamline the adoption process and maximise benefits. The case studies showcase real-world examples and best practices that other organisations can replicate or adapt, leading to enhanced efficiency, cost savings, and improved decision-making capabilities.

Methodologically, this research highlights the value of a case study approach in exploring technology adoption. It demonstrates that in-depth exploration from multiple case studies can be synthesised into a generalisable framework, offering a robust methodological template for future technology adoption studies. Furthermore, the research's multi-lens perspective emphasises the need to consider various factors and stakeholders, providing a comprehensive approach to studying technology adoption.

4.5 Limitations

There are several limitations identified in this study. The results cannot be generalised due to the specific and limited approach used. Additionally, this study concentrates on few industries i.e. agriculture, transport, and logistics. If data collection were extended to other sectors, more insights into geospatial technology management could be obtained. For future studies, it is recommended that the propositions developed be analysed using a quantitative approach to assess the relationship between the use of geospatial technology and the adoption in different business sectors. In addition to quantitative studies, research encompassing all sectors in Malaysia may reveal different aspects of geospatial technology management. A comparative study is also suggested to evaluate the factors driving the use of geospatial technology across various sectors. With in-depth knowledge and a clear understanding of this technology, it is hoped that future research can offer broader and more comprehensive insights into this field.

4.6 Conclusion

Geospatial technology has emerged as a powerful tool across diverse industries. This study demonstrates that geospatial technology facilitates the development of highly adaptable production models, enabling real-time interactions among individuals, products, and devices throughout the production process. The integration of data and geospatial technology, coupled with elements of the 4IR, illustrates its potential to offer substantial benefits for both our current and future needs. Thus, this study underscores the crucial role of geospatial technology across various industries in Malaysia, showing its significant contribution to efficiency. Within the framework of the 4IR, geospatial technology promises greatest potential for enhancing performance, thus necessitates the adoption. The management task of managing the adoption becomes paramount to accelerate the speed and breath of the adoption to maximise the return of substantial investment in the technology and amplified the macro-level outcomes.

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